Indoor Air Pollution

From: Living in the Environment
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Controlling acid deposition is a difficult political problem because **(1)** the people and ecosystems it affects often are quite distant from those who cause the problem, **(2)** countries with large supplies of coal (such as China, India, Russia, and the United States) have a strong incentive to use it as a major energy resource, and **(3)** owners of coal-burning power plants say that the costs of adding air-pollution reducing equipment, using low-sulfur coal, or removing sulfur from coal are too high.

Large amounts of limestone or lime can be used to neutralize acidified lakes or surrounding soil—the only cleanup approach now being used. However, there are several problems with liming.

- It is an expensive and temporary remedy that usually must be repeated annually. Using lime to reduce excess acidity in U.S. lakes would cost at least $8 billion per year.
- It can kill some types of plankton and aquatic plants and can harm wetland plants that need acidic water.
- It is difficult to know how much of the lime to put where (in the water or at selected places on the ground).

Recently researchers in England found that adding a small amount of phosphate fertilizer can neutralize excess acidity in a lake. However, the effectiveness of this approach is still being evaluated.

17-5 INDOOR AIR POLLUTION

What Are the Types and Sources of Indoor Air Pollution? If you are reading this book indoors, you may be inhaling more air pollutants with each breath than if you were outside (Figure 17-16). According to EPA studies, in the United States

- Levels of 11 common pollutants are generally two to five times higher inside homes and commercial buildings than outdoors and as much as 100 times higher in some cases.
- Levels of fine particles (Figure 17-7), which can contain toxins and metals such as lead and cadmium, can be as much as 60% higher indoors than outdoors.
- Concentrations of several pesticides (such as chlordane), approved for outdoor use only, were 10 times greater inside than outside monitored homes (some coming from pesticide dust tracked in on shoes).
- Pollution levels inside cars in traffic-clogged U.S. urban areas can be up to 18 times higher than those outside the vehicles.

The health risks from exposure to such chemicals are magnified because people typically spend 70–98% of their time indoors or inside vehicles. In 1990, the EPA placed indoor air pollution at the top of the list of 18 sources of cancer risk, and it is rated by risk analysis scientists as a high-risk health problem for humans (Figure 16-13, left, p. 411). According to the EPA, more than 3,000 cases of cancer per year in the United States may be caused by exposure to indoor air pollutants. At greatest risk are **(1)** smokers, **(2)** infants and children under age 5, **(3)** the old, **(4)** the sick, **(5)** pregnant women, **(6)** people with respiratory or heart problems, and **(7)** factory workers.

Danish and U.S. EPA studies have linked pollutants found in buildings to dizziness, headaches, coughing, sneezing, nausea, burning eyes, chronic fatigue, and flu-like symptoms, known as the *sick building syndrome.* New buildings are more commonly "sick" than old ones because of reduced air exchange (to save energy) and chemicals released from new carpeting and furniture. According to the EPA, at least 17% of the 4 million commercial buildings in the United States are considered "sick" (including EPA headquarters). Indoor air pollution in the United States costs an estimated $100 billion per year in absenteeism, reduced productivity, and health-care costs. Mostly because of differences in genetic makeup, some individuals can be acutely sensitive to one or a number of indoor air pollutants (Figure 16-3, p. 398).

According to the EPA and public health officials, the three most dangerous indoor air pollutants are **(1)** cigarette smoke (p. 396), **(2)** formaldehyde, and **(3)** radioactive radon-222 gas. Worker exposure to asbestos fibers in mines and in factories making asbestos material is also a serious indoor air pollution problem, especially in developing countries. A number of research studies on laboratory animals have also identified tiny fibers of *fiberglass* as a widespread and potentially potent carcinogen in indoor air.

The chemical that causes most people difficulty is *formaldehyde*, a colorless, extremely irritating gas widely used to manufacture common household materials. As many as 20 million Americans suffer from chronic breathing problems, dizziness, rash, headaches, sore throat, sinus and eye irritation, wheezing, and nausea caused by daily exposure to low levels of formaldehyde emitted (outgassed) from common household materials. These include **(1)** building materials (such as plywood, particleboard, paneling, and high-gloss wood used in floors and cabinets), **(2)** furniture, **(3)** drapes, **(4)** upholstery, **(5)** adhesives in carpeting and wallpaper, **(6)** urethane-formaldehyde insulation, **(7)** fingernail hardener, and **(8)** wrinkle-free coating on permanent-press clothing (Figure 17-16). The EPA estimates that as many as 1 of every 5,000 people who live in manufactured homes for more than 10 years will develop cancer from formaldehyde exposure.

In developing countries, the burning of wood, dung, crop residues, and coal in open fires or in unvented or poorly vented stoves for cooking and heat-

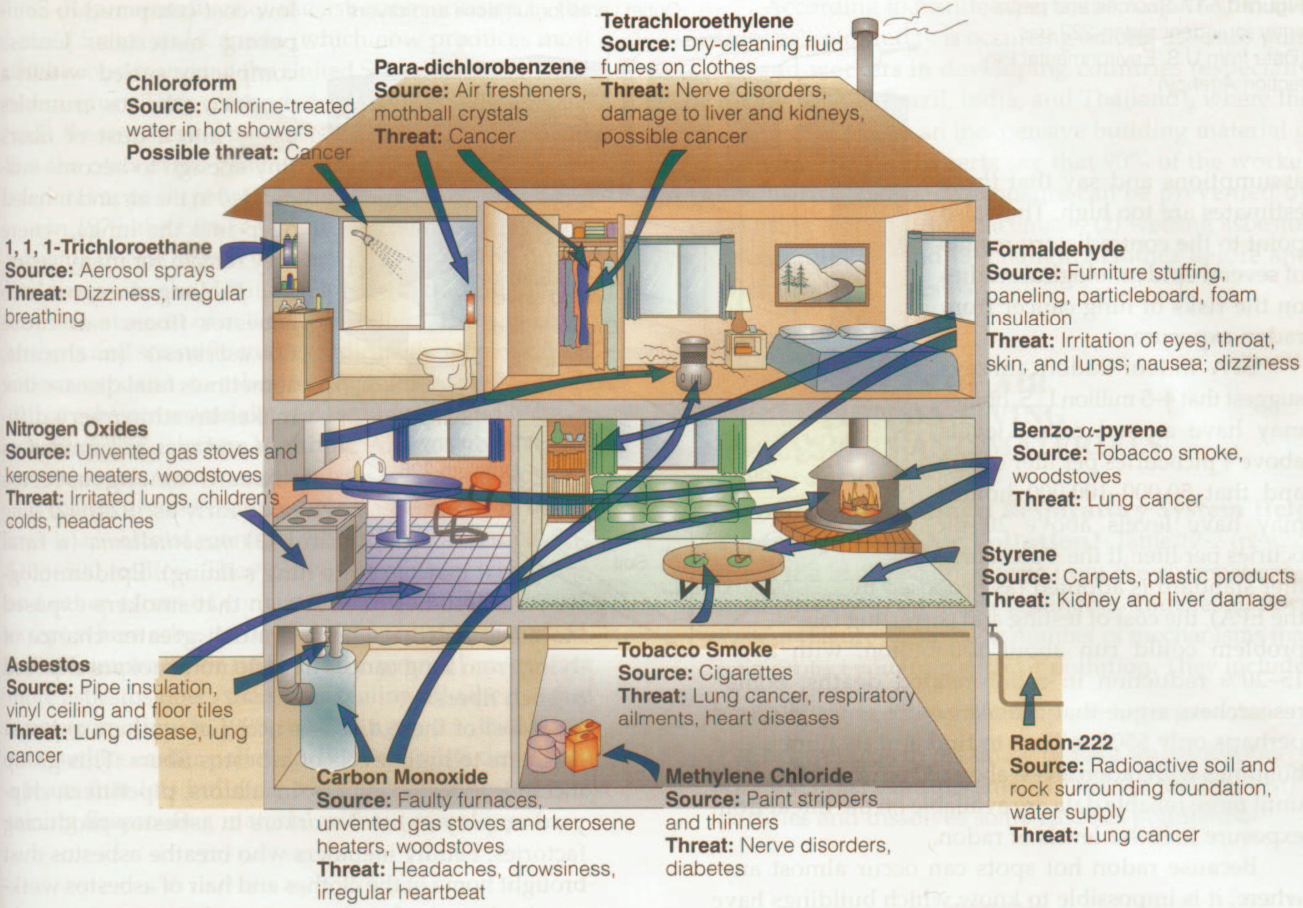


Figure 17-16 Some important indoor air pollutants. (Data from U.S. Environmental Protection Agency)

ing exposes inhabitants (especially women and young children) to very high levels of particulate air pollution.

Case Study: Is Your Home Contaminated with Radon Gas? Radon-222 is naturally occurring radioactive gas that you cannot see, taste, or smell. It is produced by the radioactive decay of uranium-238. Small amounts of uranium-238 are found in most soil and rock, but this isotope is much more concentrated in underground deposits of minerals such as uranium, phosphate, granite, and shale.

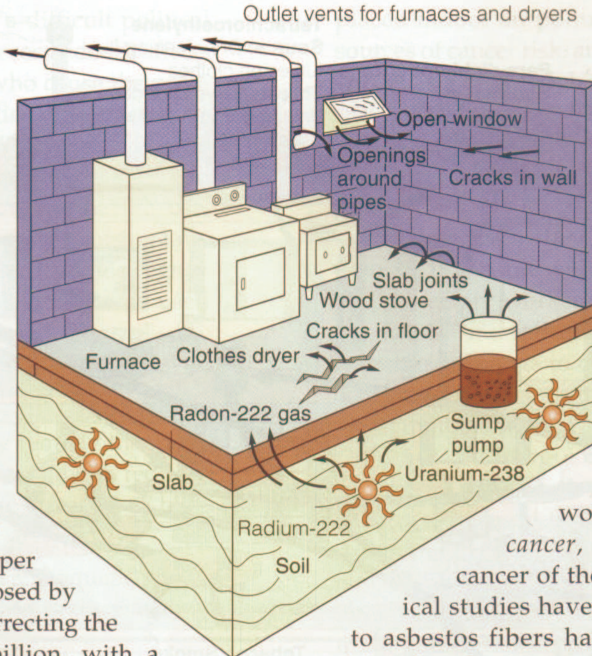
When radon gas from such deposits seeps upward through the soil and is released outdoors, it disperses quickly in the atmosphere and decays to harmless levels. However, radon gas can enter buildings above such deposits through **(1)** cracks in foundations and walls, **(2)** openings around sump pumps and drains, and **(3)** hollow concrete blocks (Figure 17-17) and build up to high levels, especially in unventilated lower levels of homes and buildings.

Radon-222 gas quickly decays into solid particles of other radioactive elements that, if inhaled, expose lung tissue to a large amount of ionizing radiation from alpha particles (Figure 3-12, p. 62). This can damage lung tissue and lead to lung cancer over the course of a 70-year lifetime. Your chances of getting lung cancer from radon depend mostly on **(1)** how much radon is in your home, **(2)** the amount of time you spend in your home, and **(3)** whether you are a smoker or have ever smoked.

In 1998, the National Academy of Science estimated that prolonged exposure for a lifetime of 70 years to low levels of radon or radon acting together with smoking is responsible for 15,000 to 22,000 (or 12%) of the lung cancer deaths each year in the United States. This makes radon the second leading cause of lung cancer after smoking (p. 396). Most of the deaths are among smokers or former smokers, with about 2,100 to 2,900 among nonsmokers.

These estimates are based on assuming that **(1)** there is no safe threshold dose for radon exposure (Figure 16-6, left, p. 401) and that **(2)** the incidence of the lung cancer in uranium miners exposed to high levels of radon in mines can be extrapolated to estimate lung cancer deaths for people in homes exposed to much lower levels of radon. Some scientists question these

Figure 17-17 Sources and paths of entry for indoor radon-222 gas. (Data from U.S. Environmental Protection Agency)



assumptions and say that these estimates are too high. They also point to the contradictory results of several epidemiological studies on the risks of lung cancer from radon exposure.

EPA indoor radon surveys suggest that 4–5 million U.S. homes may have annual radon levels above 4 picocuries per liter of air* and that 50,000–100,000 homes may have levels above 20 picocuries per liter. If the 4 picocuries per liter standard is adopted (as proposed by the EPA), the cost of testing and correcting the problem could run about $50 billion, with a 15–20% reduction in radon-related deaths. Some researchers argue that it makes more sense to spend perhaps only $500 million to find and fix homes and buildings with radon levels above 20 picocuries per liter until more reliable data are available on the threat from exposure to lower levels of radon.

Because radon hot spots can occur almost anywhere, it is impossible to know which buildings have unsafe levels of radon without conducting tests. In 1988, the EPA and the U.S. Surgeon General's Office recommended that everyone living in a detached house, a town house, a mobile home, or on the first three floors of an apartment building test for radon. Ideally, radon levels should be monitored continuously in the main living areas (not basements or crawl spaces) for 2 months to a year. By 2000, only about 6% of U.S. households had conducted radon tests (most lasting only 2 to 7 days and costing $20–100 per home).

If testing reveals an unacceptable level, homeowners can consult the free EPA publication *Radon Reduction Methods* for ways to reduce radon levels and health risks. According to the EPA, radon control could add $350–500 to the cost of a new home, and correcting a radon problem in an existing house could run $800–2,500.

Case Study: What Should Be Done About Asbestos?

Asbestos is a name given to several different fibrous forms of silicate minerals. For decades it has been widely used as a building material and for large water pipelines because of its strength, flexibility, and low cost compared to competing materials. Unless completely sealed within a product, asbestos crumbles easily into a dust of fibers tiny enough to become suspended in the air and inhaled deep into the lungs, where they remain for many years.

Prolonged exposure to asbestos fibers can cause **(1)** *asbestosis* (a chronic, sometimes fatal disease that makes breathing very difficult and was recognized as a hazard among asbestos workers as early as 1924), **(2)** *lung cancer*, and **(3)** *mesothelioma* (a fatal cancer of the lung's lining). Epidemiological studies have shown that smokers exposed to asbestos fibers have a much greater chance of dying from lung cancer than do nonsmokers exposed to such fibers.

Most of these diseases occur in workers exposed for years to high levels of asbestos fibers. This group includes asbestos miners, insulators, pipefitters, shipyard employees, and workers in asbestos-producing factories. Family members who breathe asbestos dust brought home in the clothes and hair of asbestos workers also have higher than expected cancer rates, as do people who live near asbestos manufacturing plants with inadequate control of asbestos emissions.

According to health officials, asbestos fibers caused the premature cancer deaths of almost 172,000 asbestos workers in the United States between 1967 and 2000, the worst occupational health disaster of the 20th century. An additional 119,000 premature cancer deaths among U.S. asbestos workers are predicted between 2000 and 2025, mostly from workers exposed to unsafe conditions before working conditions were improved.

After being swamped with health claims from workers, most U.S. asbestos manufacturing companies either declared bankruptcy or moved their operations to other countries (such as Mexico and Brazil) with weaker environmental laws and lax enforcement.

Since 1980 the focus in the United States has shifted to the possible health effects of low levels of asbestos fibers in buildings on the general public. Between 1900 and 1984, asbestos was sprayed on ceilings and walls of schools and other public and private buildings in the United States for fireproofing, soundproofing, insulation of heaters and pipes, and wall and ceiling decoration. The EPA banned those uses in 1984.

In 1989, the EPA ordered a ban on almost all remaining uses of asbestos (such as brake linings, roofing shingles, and water pipes) in the United States by

*A *picocurie* is a trillionth of a curie, which is the amount of radioactivity emitted by a gram of radium.

1997. Representatives of the asbestos industry in the United States and Canada (which now produces most of the asbestos used in the United States) challenged the ban in court. They contended that with proper precautions these asbestos products can be used safely and that the costs of the ban outweigh the benefits. In 1991, a federal appeals court overturned the 1989 EPA ban.

In 1979, the EPA recommended removing existing asbestos in one of every seven commercial and public buildings in the United States (including 30,000 schools), at a cost of at least $100 billion. However, risk analysis and scientific studies indicate that the risk from indoor exposure to asbestos fibers (even in buildings rich in asbestos materials) is extremely low and is about one-tenth the risk from breathing asbestos fibers found in outdoor air from natural sources (wind and erosion).

Critics argued that removing asbestos from buildings is a waste of money, with each life saved costing $100–500 million. They called for sealing, wrapping, and other forms of containment instead of removal, except where asbestos has been damaged or disturbed. Indeed, improper or unnecessary removal can release more asbestos fibers than does sealing off asbestos that is not crumbling. In 1990, the EPA agreed with this and reversed its earlier policy. In 1998, chemists developed a foam that lets building owners treat asbestos-containing fireproofing material without removing it.

According to health experts, the major health risk from asbestos today is occurring among asbestos miners and workers in developing countries (especially Russia, China, Brazil, India, and Thailand), where the use of asbestos as an inexpensive building material is growing rapidly. Experts say that 90% of the worker deaths from asbestos exposure can be prevented by **(1)** using a good-fitting facemask, **(2)** wetting asbestos to control dust, and **(3)** changing clothes before and after handling asbestos.

17-6 EFFECTS OF AIR POLLUTION ON LIVING ORGANISMS AND MATERIALS

How Does the Human Respiratory System Help Protect Us from Air Pollution? Table 17-2 (p. 422) listed the major health effects from the six most common (criteria) outdoor air pollutants. Your respiratory system (Figure 17-18) has a number of mechanisms that help protect you from such air pollution. They include:

- Hairs in your nose that filter out large particles.
- Sticky mucus in the lining of your upper respiratory tract that captures smaller (but not the smallest) particles and dissolves some gaseous pollutants.

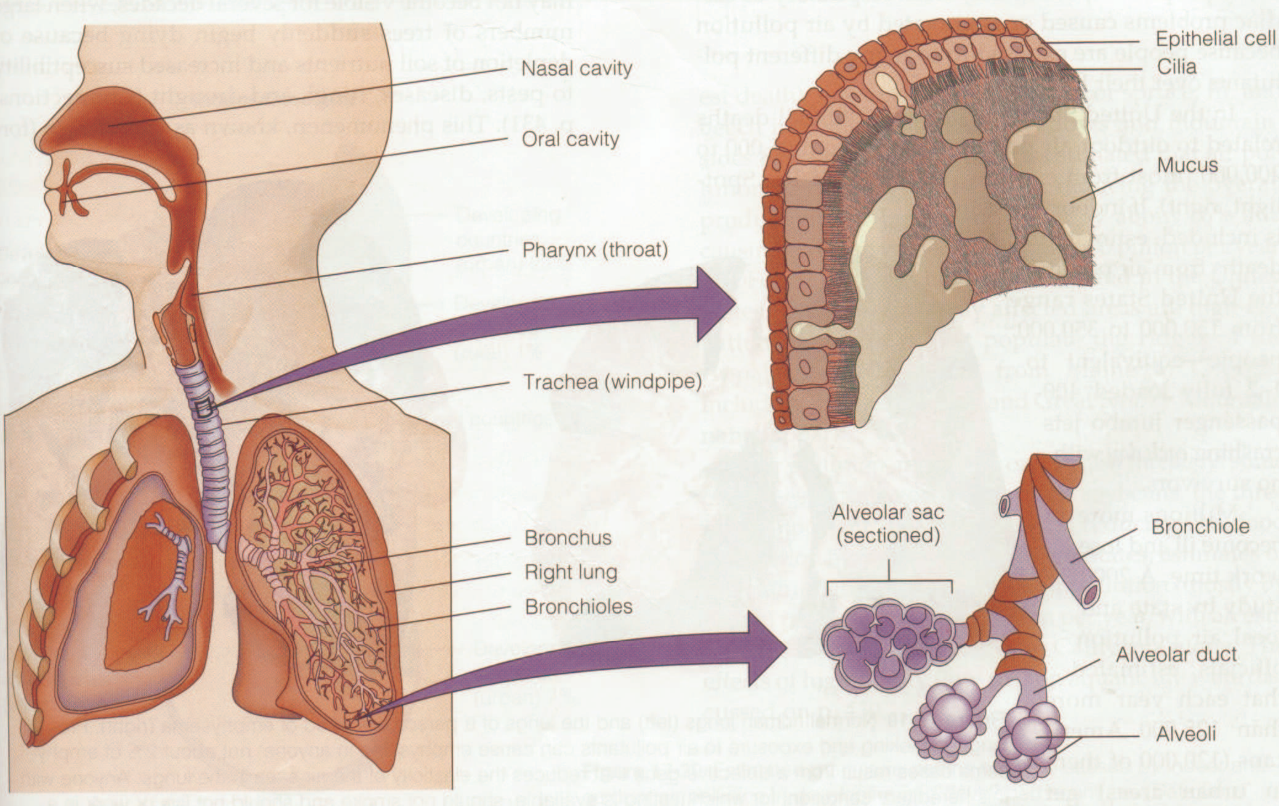


Figure 17-18 Major components of the human respiratory system.

- Sneezing and coughing that expel contaminated air and mucus when pollutants irritate your respiratory system.
- Hundreds of thousands of tiny, mucus-coated hairlike structures called *cilia* that line your upper respiratory tract. They continually wave back and forth and transport mucus and the pollutants they trap to your throat (where they are swallowed or expelled).

Years of smoking and exposure to air pollutants can overload or break down these natural defenses. This can cause or contribute to respiratory diseases such as **(1)** *lung cancer*, **(2)** *asthma* (typically an allergic reaction causing sudden episodes of muscle spasms in the bronchial walls, resulting in acute shortness of breath), **(3)** *chronic bronchitis* (persistent inflammation and damage to the cells lining the bronchi and bronchioles, causing mucus buildup, painful coughing, and shortness of breath), and **(4)** *emphysema* (irreversible damage to air sacs or alveoli leading to abnormal dilation of air spaces, loss of lung elasticity, and acute shortness of breath (Figure 17-19). Older adults, infants, pregnant women, and people with heart disease, asthma, or other respiratory diseases are especially vulnerable to air pollution.

How Many People Die Prematurely from Air Pollution? It is difficult to estimate by risk analysis how many people die prematurely from respiratory or cardiac problems caused or aggravated by air pollution because people are exposed to so many different pollutants over their lifetimes.

In the United States, estimates of annual deaths related to outdoor air pollution range from 65,000 to 200,000 (most from exposure to fine particles, Spotlight, right). If indoor air pollution is included, estimated annual deaths from air pollution in the United States range from 150,000 to 350,000 people—equivalent to 1–2 fully loaded 400-passenger jumbo jets crashing *each day* with no survivors.

Millions more become ill and lose work time. A 2000 study by state and local air pollution officials estimated that each year more than 125,000 Americans (120,000 of them in urban areas) get cancer from breathing diesel fumes from buses, trucks, and other diesel engines. According to the EPA and the American Lung Association, air pollution in the United States costs at least $150 billion annually in health care and lost work productivity, with $100 billion of that caused by indoor air pollution.

According to a 1999 study by Australia's Commonwealth Science Council, worldwide at least 3 million people (most of them in Asia) die prematurely each year from the effects of air pollution—an average of 8,200 deaths per day. About 2.8 million of these deaths are from *indoor* air pollution, and 200,000 are from *outdoor* pollution (Figure 17-20).

Most people who live in large cities in developing countries breathe air that is the equivalent of smoking 2–3 packs of cigarettes a day. According to WHO estimates, up to 700,000 premature deaths per year worldwide could be prevented in developing countries if three pollutants—suspended particulate matter, carbon monoxide, and lead—were brought down to safer levels.

How Are Plants and Aquatic Systems Damaged by Air Pollutants? Figure 17-14 (p. 432) summarizes some of the direct and indirect effects of acidic deposition, ozone, and other air pollutants on trees, and the effects of acid deposition on trees and plants were discussed on p. 431.

The effects of exposure to a mix of air pollutants may not become visible for several decades, when large numbers of trees suddenly begin dying because of depletion of soil nutrients and increased susceptibility to pests, diseases, fungi, and drought (Connections, p. 431). This phenomenon, known as *Waldsterben* (for-

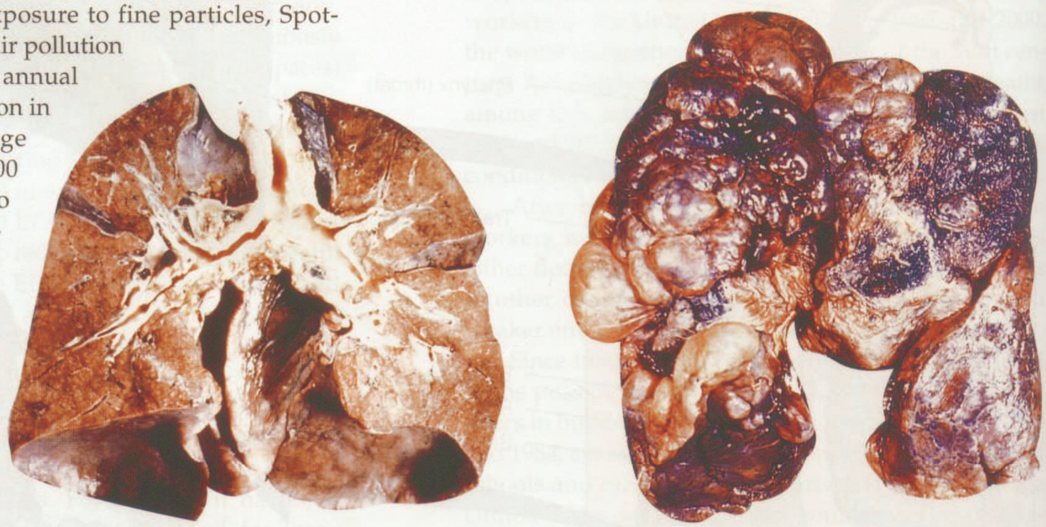


Figure 17-19 Normal human lungs (left) and the lungs of a person who died of emphysema (right). Prolonged smoking and exposure to air pollutants can cause emphysema in anyone, but about 2% of emphysema cases result from a defective gene that reduces the elasticity of the air sacs in the lungs. Anyone with this hereditary condition, for which testing is available, should not smoke and should not live or work in a highly polluted area. (O. Auerbach/Visuals Unlimited)

SPOTLIGHT

Health Dangers from Fine Particles

Research indicates that invisible particles—especially *fine particles* with diameters less than 10 microns (PM-10) and *ultrafine particles* with diameters less than 2.5 microns (PM-2.5)—pose a significant health hazard. Such particles are emitted by incinerators, motor vehicles, radial tires, wind erosion, wood-burning fireplaces, and power and industrial plants (Figure 17-7).

Such tiny particles **(1)** are not effectively captured by modern air-pollution control equipment, **(2)** are small enough to penetrate the respiratory system's natural defenses against air pollution (Figure 17-18), and **(3)** can bring with them droplets or other particles of toxic or cancer-causing pollutants that become attached to their surfaces.

Once they are lodged deep within the lungs, these fine particles can cause chronic irritation that can **(1)** trigger asthma attacks, **(2)** aggravate other lung diseases, **(3)** cause lung cancer, and **(4)** interfere with the blood's ability to take in oxygen and release CO_2. This strains the heart, increasing the risk of death from heart disease.

Several recent studies of air pollution in U.S. cities have indicated that fine and ultrafine particles prematurely kill 65,000–200,000 Americans each year. There is no known threshold level below which the harmful effects of fine particles disappear.

Exposure to particulate air pollution is much worse in most developing countries, where urban air quality has generally deteriorated. The World Bank estimates that if particulate levels were reduced globally to WHO guidelines, 300,000–700,000 premature deaths per year could be prevented.

In 1997, the EPA announced stricter emission standards for ultrafine particles with diameters less than 2.5 microns (PM-2.5). The EPA estimates the cost of implementing the standards at $7 billion per year, with the resulting health and other benefits estimated at $120 billion per year.

According to industry officials, the new standard is based on flimsy scientific evidence, and its implementation will cost $200 billion per year. EPA officials say that their review of the scientific evidence—one of the most exhaustive ones ever undertaken by the agency—supports the need for the new standard for ultrafine particles. Furthermore, a 2000 study by the Health Effects Institute of 90 large American cities confirmed the link between fine and ultrafine particles and higher rates of death and disease.

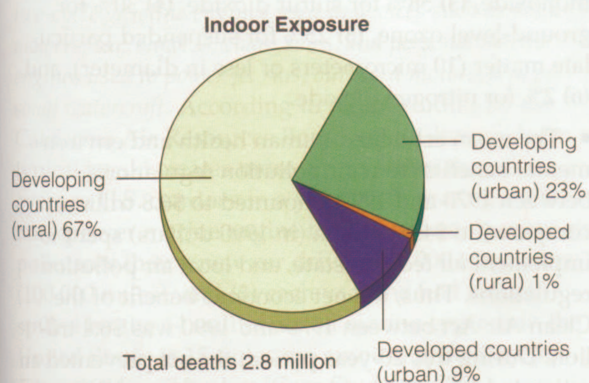
Critical Thinking

Are you for or against the stricter standard for emissions of ultrafine particles? Explain.

est death), has turned whole forests of spruce, fir, and beech into stump-studded meadows and mountainsides (see photo on p. 395). It is estimated that air pollution has been a key factor in reducing the overall productivity of European forests by about 16% and causing damage valued at roughly $30 billion per year.

Forest diebacks have also occurred in the United States. The most seriously affected areas are high-elevation spruce trees that populate the ridges of the Appalachian Mountains from Maine to Georgia, including the Shenandoah and Great Smoky Mountain national parks.

Air pollution, mostly by ozone, also threatens some crops—especially corn, wheat, and soybeans, the three most important U.S. crops—and is reducing U.S. food production by 5–10%. In the United States, estimates of agricultural losses as a result of air pollution (mostly by ozone) range from $2 to $6 billion per year, with an estimated $1 billion of damages in California alone. The effects of high acidity (low pH) on aquatic life were discussed on p. 430.



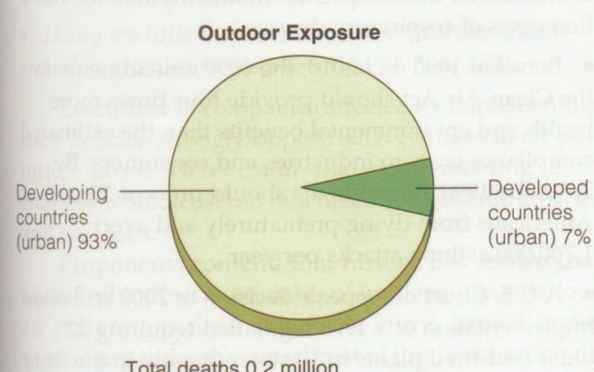


Figure 17-20 Estimated premature deaths per year caused by indoor and outdoor air pollution in developing and developed countries. (Data from Australia's Commonwealth Science Council, 2000)

Table 17-3 Harmful Effects of Air Pollution on Materials

Material	Effects	Principal Air Pollutants
Stone and concrete	Surface erosion, discoloration, soiling	Sulfur dioxide, sulfuric acid, nitric acid, particulate matter
Metals	Corrosion, tarnishing, loss of strength	Sulfur dioxide, sulfuric acid, nitric acid, particulate matter, hydrogen sulfide
Ceramics and glass	Surface erosion	Hydrogen fluoride, particulate matter
Paints	Surface erosion, discoloration, soiling	Sulfur dioxide, hydrogen sulfide, ozone, particulate matter
Paper	Embrittlement, discoloration	Sulfur dioxide
Rubber	Cracking, loss of strength	Ozone
Leather	Surface deterioration, loss of strength	Sulfur dioxide
Textiles	Deterioration, fading, soiling	Sulfur dioxide, nitrogen dioxide, ozone, particulate matter

What Are the Harmful Effects of Air Pollutants on Materials? Each year, air pollutants cause billions of dollars in damage to various materials we use (Table 17-3). The fallout of soot and grit on buildings, cars, and clothing requires costly cleaning. Air pollutants break down exterior paint on cars and houses, and they deteriorate roofing materials. Irreplaceable marble statues, historic buildings, and stained glass windows around the world have been pitted, gouged, and discolored by air pollutants. The EPA estimates damage to buildings in the United States from acid deposition alone at $5 billion per year.

17-7 SOLUTIONS: PREVENTING AND REDUCING AIR POLLUTION

How Have Laws Been Used to Reduce Air Pollution in the United States? The U.S. Congress passed Clean Air Acts in 1970, 1977, and 1990. These laws use a *command-and-control* approach in which the federal government establishes air pollution regulations that are enforced by each state and by major cities.

Congress directed the EPA to establish *national ambient air quality standards (NAAQS)* for six outdoor criteria pollutants (Table 17-2). The EPA regulates these chemicals by using *criteria* developed from risk assessment methods (Section 16-2, p. 398) to set maximum permissible levels in outdoor air.

One limit, called a *primary standard*, is set to protect human health, and another called a *secondary standard*, is intended to prevent environmental and property damage. Each standard specifies the maximum allowable level, averaged over a specific period, for a certain pollutant in outdoor (ambient) air. A geographic area that meets or does better than the primary standard for a particular pollutant is called an *attainment area*, and one that does not meet the primary standard is called a *nonattainment area*.

The EPA has also established national emission standards for more than 100 different toxic air pollutants that are known to cause or suspected of causing cancer or other adverse health effects.

Here is some *good news*. According to the EPA,

- Between 1970 and 1998, national total emissions of the six criteria pollutants declined 31%, while U.S. population increased 31%, gross domestic product increased 114%, and vehicle miles traveled rose 127%.
- Between 1978 and 1998, mean concentrations of the six criteria air pollutants in the troposphere decreased by **(1)** 97% for lead, **(2)** 60% for carbon monoxide, **(3)** 58% for sulfur dioxide, **(4)** 30% for ground-level ozone, **(5)** 25% for suspended particulate matter (10 micrometers or less in diameter), and **(6)** 2% for nitrogen dioxide.
- The mean estimated human health and environmental benefits from air pollution regulations between 1970 and 1990 amounted to $6.8 trillion, compared to $436 million (in 1990 dollars) spent to implement all federal, state, and local air pollution regulations. Thus, the net economic benefit of the Clean Air Act between 1970 and 1990 was $6.4 trillion. During this 20-year period, the act prevented an estimated 1.6 million premature deaths and 300 million cases of respiratory disease.
- Between 1990 and 2010, the 1990 amendments to the Clean Air Act should provide four times more health and environmental benefits than the estimated compliance costs to industries and consumers. By 2010, the 1990 amendments should prevent 23,000 Americans from dying prematurely and avert 1,700,000 asthma attacks per year.
- A U.S. Court of Appeals decision in 2000 will allow implementation of a 1998 regulation requiring 32 older coal-fired plants in 10 states (mostly in the Ohio Valley and Midwest, Figure 17-10) to meet the same

air pollution emission standards as new coal-burning plants. According to the EPA, this will have the same effect as taking 26 million cars off the road and will bring cleaner, safer air to more than 138 million people living in the eastern half of the United States.

Here is some *bad news*.

- Between 1970 and 1998, emissions of nitrogen oxides (NO_x) increased 11%.
- Despite continued improvements in air quality, in 1999 approximately 62 million people lived in 130 nonattainment areas with air that did not meet the primary standards for one or more of the six criteria pollutants.

How Could U.S. Air Pollution Laws Be Improved? The Clean Air Act of 1990 was an important step in the right direction, but many environmentalists point to the following deficiencies in this law:

- *Continuing to rely mostly on pollution cleanup rather than prevention.* In the United States, the air pollutant with the largest drop (97% between 1970 and 1998) in its atmospheric level was lead, which was virtually banned in gasoline.
- *Failing to increase fuel efficiency standards for cars and light trucks.* According to environmental scientists, this would reduce air pollution more quickly and effectively than any other method and would save consumers enormous amounts of money (p. 364).
- *Not adequately regulating emissions from inefficient, two-cycle gasoline engines used in devices such as lawnmowers, leaf blowers, chain saws, and personal marine engines used to power jet skis, outboard motors, and personal watercraft.* According to recent studies by the California Air Resources Board, **(1)** a 1-hour ride on a typical jet ski creates more air pollution than the average U.S. car does in a year, **(2)** operating a 100-horsepower marine engine for 7 hours emits more air pollutants than a new car driven 160,000 kilometers (100,000 miles), and **(3)** each year the fuel and oil spilled by the 14 million small marine engines in the United States is 15 times the amount spilled by the *Exxon Valdez* oil tanker (Case Study, p. 336).
- *Doing too little to reduce emissions of carbon dioxide and other greenhouse gases* (Section 18-5, p. 460).

Executives of companies affected by implementing such policies strongly oppose such changes in air pollution laws. They claim that implementing such changes would cost too much, harm economic growth, and cost jobs.

Proponents contend that history has shown that almost all industry estimates of implementing various air pollution control standards in the United States were many times the actual cost of implementation. In addition, implementing such standards has helped increase economic growth and create jobs by stimulating companies to develop new technologies for reducing air pollution emissions. Many of these technologies are sold in the international marketplace.

Should We Use the Marketplace to Reduce Pollution? To help reduce SO_2 emissions, the Clean Air Act of 1990 allows an *emissions trading policy*, which enables the 110 most polluting power plants in 21 states (primarily in the Midwest and East, Figure 17-10) to buy and sell SO_2 pollution rights.

Each year a power plant is given a certain number of pollution credits or rights that allow it to emit a certain amount of SO_2. A utility that emits less SO_2 than its limit receives more pollution credits. It can use these credits **(1)** to avoid reductions in SO_2 emissions from some of its other facilities, **(2)** bank them for future plant expansions, or **(3)** sell them to other utilities, private citizens, or environmental groups. Proponents of this system argue that it allows the marketplace to determine the cheapest, most efficient way to get the job done instead of having the government dictate how to control pollution.

Some environmentalists see this market approach as an improvement over the current regulatory approach, as long as it achieves net reduction in SO_2 pollution. This would be done by limiting the total number of credits and gradually lowering the annual number of credits, something that is not required by the 1990 amendments to the Clean Air Act.

Some environmentalists contend that marketing pollution rights allows utilities with older, dirtier power plants to buy their way out and keep on emitting unacceptable levels of SO_2. They also warn that this approach creates incentives to cheat. Air quality regulation is based largely on self-reporting of emissions, and pollution monitoring is incomplete and imprecise. Thus, sellers of permits will benefit by understating their reductions (to get more permits), and permit buyers will benefit by underreporting emissions (to reduce their permit purchases).

Here is some *good news*. Between 1994 and 1997, the emission trading system helped reduce SO_2 emissions in the United States by 30%. The cost of doing this was less than one-tenth the cost projected by industry because this market-based system motivated companies to reduce emissions in more efficient ways.

In 1997, the EPA proposed a voluntary emissions trading program involving smog-forming nitrogen oxides (NO_x) for 22 eastern states and the District of Columbia. Emissions trading may also be implemented for particulate emissions and volatile organic compounds.

How Can We Reduce Outdoor Air Pollution? Figure 17-21 summarizes ways to reduce emissions of sulfur oxides, nitrogen oxides, and particulate matter from stationary sources (such as electric power plants and industrial plants that burn coal). Until recently, emphasis has been on dispersing and diluting the pollutants

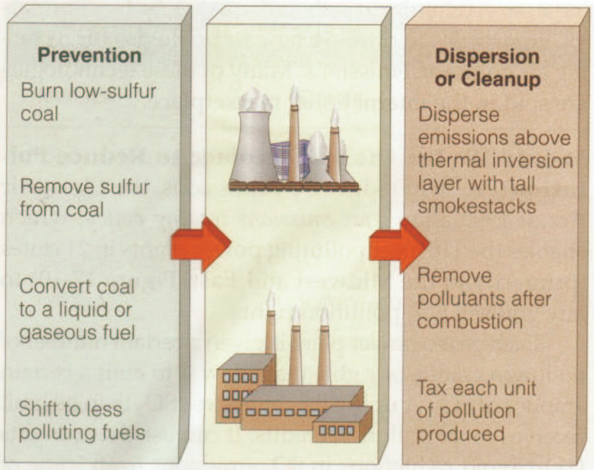


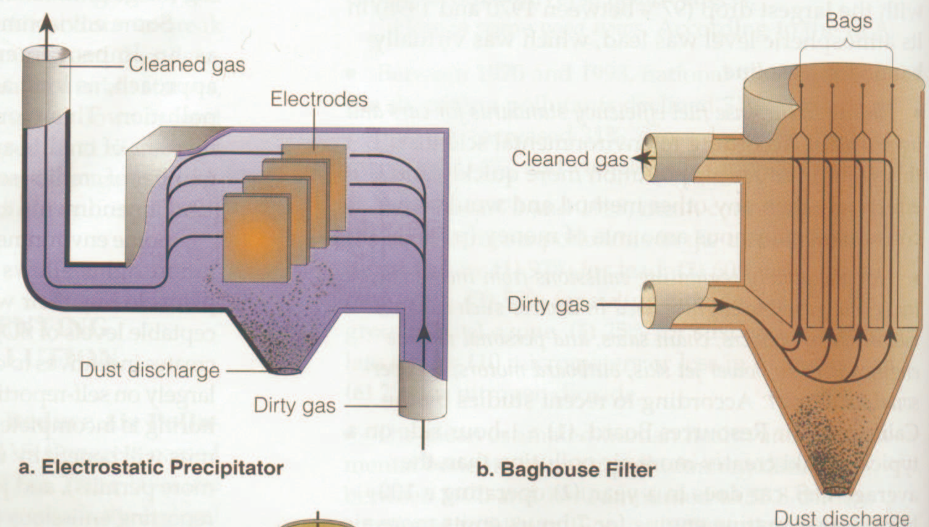
Figure 17-21 Solutions: methods for reducing emissions of sulfur oxides, nitrogen oxides, and particulate matter from stationary sources such as coal-burning electric power plants and industrial plants.

by using tall smokestacks or adding equipment that removes some of the particulate pollutants after they are produced (Figure 17-22). However, under the sulfur reduction requirements of the 1990 amendments to the Clean Air Act, more utilities are switching to low-sulfur coal to reduce SO_2 emissions. Environmentalists call for taxes on air pollutant emissions and greater emphasis on prevention.

Figure 17-23 lists ways to reduce emissions from motor vehicles, the primary culprits in producing photochemical smog. Use of alternative vehicle fuels to reduce air pollution is evaluated in Table 15-1, p. 385.

An important way to make significant reductions in air pollution is to get older, high-polluting vehicles off the road. According to EPA estimates, 10% of the vehicles on the road in the United States emit 50–70% of the pollutants. A problem is that many old cars are owned by people who cannot afford to buy a newer car. One suggestion would be to pay people to take their old cars off the road, which would result in huge savings in health and air-pollution control costs.

California's South Coast Air Quality Management District Council developed a drastic and controversial program to produce an 80% reduction in ozone, photochemical smog, and other major air pollutants in the Los Angeles area by 2009. This plan would **(1)** sharply reduce use of gasoline-burning engines over two decades by converting cars, trucks, buses, chain saws, outboard motors, and lawnmowers to run on electricity or alternative fuels, **(2)** substantially raise parking fees and assess high fees for families owning more than one car, **(3)** require gas stations to use a hydrocarbon vapor recovery system on gas pumps and to sell alternative



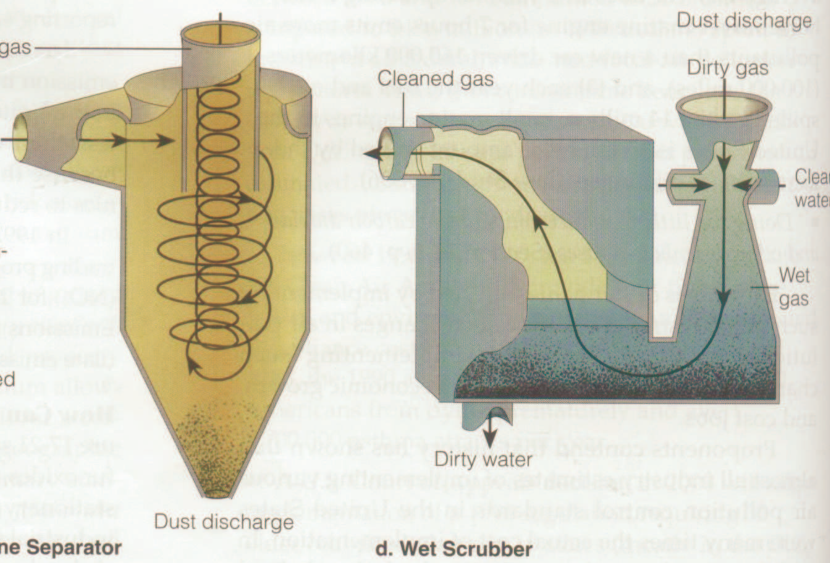


Figure 17-22 Solutions: four commonly used methods for removing particulates from the exhaust gases of electric power and industrial plants. Of these, only baghouse filters remove many of the more hazardous fine particles. All these methods produce hazardous materials that must be disposed of safely, and except for cyclone separators, all of them are expensive. The wet scrubber can also reduce sulfur dioxide emissions.

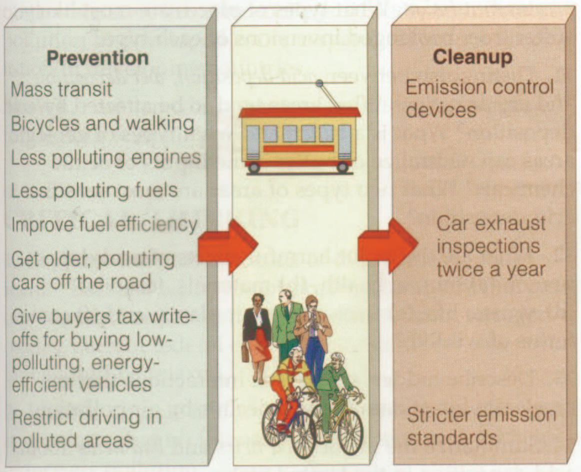


Figure 17-23 Solutions: methods for reducing emissions from motor vehicles.

fuels (Table 15-1, p. 385), **(4)** strictly control or relocate industrial plants and businesses that release large quantities of hydrocarbons and other pollutants, and **(5)** find substitutes for or ban consumer products that release hydrocarbons, including aerosol propellants, paints, household cleaners, and barbecue starter fluids.

Here is some *good news*. Since the 1960s, Tokyo, Japan (with a current population of about 28 million), has implemented a strict air-pollution control program that has sharply reduced levels of sulfur dioxide, carbon monoxide, and ozone. During the past 30 years outdoor air quality in most western European cities has also improved. The *bad news* is that outdoor air quality has remained about the same or has gotten worse in most rapidly growing urban areas in developing countries.

How Can We Reduce Indoor Air Pollution? In the United States indoor air pollution poses a much greater health risk for many people than outdoor air pollution. Yet the EPA spends about $500 million per year fighting outdoor air pollution and only about $13 million a year on indoor air pollution.

To reduce indoor air pollution, it is not necessary to impose indoor air quality standards and monitor the more than 100 million homes and buildings in the United States. Instead, air pollution experts suggest that indoor air pollution can be reduced by several means (Figure 17-24). Another possibility for cleaner indoor air in high-rise buildings is rooftop greenhouses through which building air can be circulated. Some actions you can take to reduce your exposure to indoor air pollutants are listed in Appendix 6.

In developing countries, indoor air pollution from open fires and leaky and inefficient stoves that burn wood, charcoal, or coal (and the resulting high levels of respiratory illnesses) could be reduced if governments

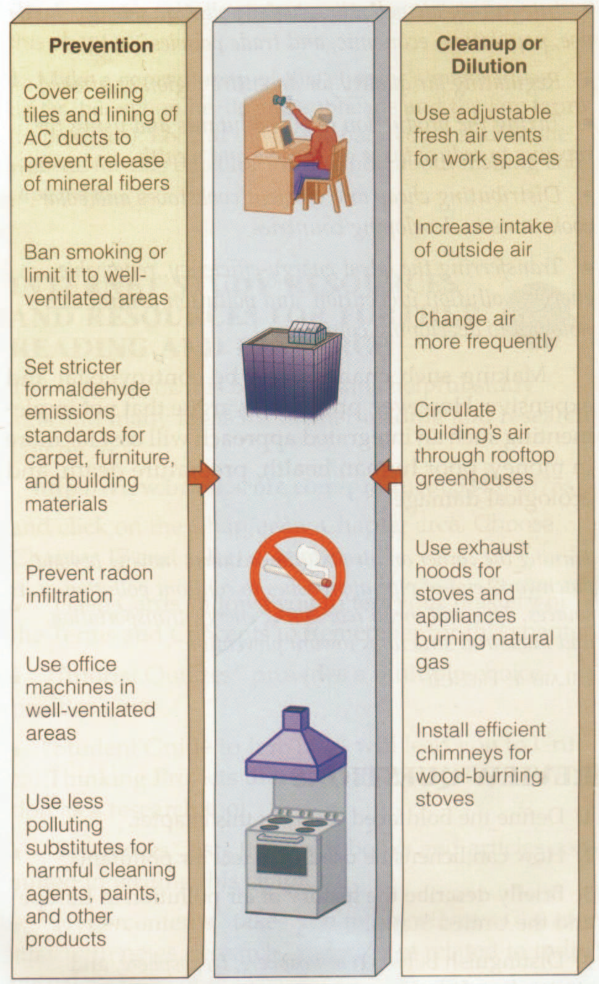


Figure 17-24 Solutions: ways to prevent and reduce indoor air pollution.

(1) gave people simple stoves that burn biofuels more efficiently (which would also reduce deforestation) and that are vented outside or **(2)** provided them with simple solar cookers (Figure 15-21d, p. 374).

How Can We Protect the Atmosphere? An Integrated Approach Environmentalists believe that protecting the atmosphere, and thus the health of people and many other organisms, will take a global approach that integrates many different strategies. Suggestions for doing this over the next 40–50 years include the following:

- *Putting more emphasis on pollution prevention*
- *Improving energy efficiency*
- *Reducing use of fossil fuels (especially coal and oil)*
- *Increasing use of renewable energy*
- *Slowing population growth*

- *Integrating air pollution, water pollution, energy, land-use, population, economic, and trade policies*
- *Regulating air quality for an entire region or airshed*
- *Taxing the production of air pollutants and using the revenue to reduce taxes on income and wealth*
- *Distributing cheap and efficient cookstoves and solar cookstoves in developing countries*
- *Transferring the latest energy-efficiency, renewable-energy, pollution prevention, and pollution control technologies to developing countries*

Making such changes will be controversial and expensive. However, proponents argue that not implementing such an integrated approach will cost far more in money, poor human health, premature death, and ecological damage.

Turning the corner on air pollution requires moving beyond patchwork, end-of-pipe approaches to confront pollution at its sources. This will mean reorienting energy, transportation, and industrial structures toward prevention.

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REVIEW QUESTIONS

1. Define the boldfaced terms in this chapter.

2. How can lichens be used to detect air pollutants?

3. Briefly describe the history of air pollution in Europe and the United States.

4. Distinguish between *atmosphere*, *troposphere*, and *stratosphere*. What key role does the stratosphere play in maintaining life on the earth?

5. Distinguish between the *greenhouse effect* and *the ozone shield* and explain the importance of these natural processes in sustaining life on the earth.

6. Explain how human activities are disrupting the carbon, nitrogen, and sulfur biogeochemical cycles.

7. Distinguish between *air pollution*, *primary air pollutants*, and *secondary air pollutants*. List the major classes of pollutants found in outdoor air. Distinguish between *stationary* and *mobile* sources of pollution for outdoor air. What are the two major sources of indoor air pollution?

8. List the six *criteria* air pollutants regulated in the United States (and in most developed countries). For each of these pollutants, summarize its major human sources and health effects.

9. What is *photochemical smog*, and how does it form? What is *industrial smog*, and how does it form?

10. List major factors that can **(a)** reduce air pollution and **(b)** increase air pollution. What is a *temperature inversion*, and what are its harmful effects? Distinguish between a *subsidence thermal inversion* and a *radiation temperature inversion*. What types of places are most likely to suffer from prolonged inversions of each type?

11. Distinguish between *acid deposition*, *wet deposition*, and *dry deposition*. What areas tend to be affected by acid deposition? What is a *buffer*, and what types of geologic areas can neutralize or buffer some inputs of acidic chemicals? What two types of areas are most sensitive to acid deposition?

12. What are the major harmful effects of acid deposition on **(a)** human health, **(b)** materials, **(c)** soils, **(d)** aquatic life, **(e)** trees and other plants, and **(f)** some forms of wildlife?

13. Describe hidden synergistic interactions that can accelerate forest damage and decline by air pollution.

14. Summarize the major *good news* and *bad news* about acid deposition in the United States.

15. List seven ways to prevent acid deposition. What are the advantages and disadvantages of liming acidified lakes to reduce the effects of acid deposition?

16. How serious is indoor air pollution, and what are some of its sources? What is the *sick-building syndrome*? According to the EPA, what are the three most dangerous indoor air pollutants in the United States? What is the most dangerous indoor air pollutant in most developing countries?

17. Summarize the problem of indoor pollution from **(a)** formaldehyde, **(b)** radioactive radon gas, and **(c)** asbestos fibers.

18. List four defenses your body has against air pollution. What are the major harmful health effects of **(a)** carbon monoxide, **(b)** suspended particulate matter, **(c)** sulfur dioxide, **(d)** nitrogen oxides, and **(e)** ozone (See Table 17-2, p. 422)? Describe the health dangers from inhaling fine particles.

19. About how many people die prematurely each year from exposure to air pollutants in **(a)** the United States and **(b)** the world? What percentage of these deaths occurs in developing countries? What percentage of these deaths is the result of indoor air pollution?

20. What is the Clean Air Act, and how has it helped reduce outdoor air pollution in the United States? Distinguish between *national ambient air quality standards*, *primary standards*, and *secondary standards*. Distinguish between *attainment* and *nonattainment areas*.

21. Summarize the major *good news* and *bad news* about the effectiveness of the Clean Air Act in reducing outdoor air pollution in the United States. According to environmentalists, what are four weaknesses of the current Clean Air Act in the United States?

22. What is an *emission trading policy*, and what are the pros and cons of using this approach to help reduce air pollution?

23. List the major prevention and cleanup methods for dealing with air pollution from **(a)** emissions of sulfur oxides, nitrogen oxides, and particulate matter from sta-